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(54) Refrigeration/air conditioning system

(57) A two-phase mechanical refrigeration system, particularly suitable for operation in accordance with the carbon dioxide trans-critical cycle, utilises energy produced on expansion to pre-compress refrigerant returning to a primary compressor (21), thereby improving the overall performance and efficiency of the system and of the primary compressor (21). The system finds application in refrigeration and air conditioning systems, and in heat pumps.

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Description

Field of the Invention

[0001] The present invention relates to a two-phase mechanical refrigeration system and its use in refrigeration and/or air conditioning applications.

Background to the Invention

[0002] Conventional two-phase refrigeration cycles involve compression of a gas to high temperature and pressure, usually with a concomitant change of a state to a liquid, constant throttling of the liquid, and then evaporation of the liquid to a gas at low temperature and pressure. Advantage is usually taken of the energy changes occurring on compression and/or evaporation to achieve heating and/or cooling effects, respectively. A system working on such a cycle is commonly referred to as running on the vapour compression cycle.

[0003] The precise design of a vapour compression cycle is dependent upon the thermodynamic properties of the material to be used in the system. Hydrofluorocarbons (HFCs) are widely used as refrigerants in domestic and commercial refrigeration and in the air conditioning of buildings, ships and automobiles. Natural refrigerants, such as ammonia, are also used quite widely in industrial refrigeration. Another natural refrigerant is carbon dioxide. This was used extensively on ships in the early part of this century, but fell out of favour on the introduction of "Freons" or chlorofluorocarbons (CFCs) because of the extremely high pressures generated in the vapour compression cycle. Unlike the CFCs, however, carbon dioxide is non-toxic, non-flammable and environmentally-friendly, having zero ozone depletion potential. Carbon dioxide is also readily available and therefore inexpensive. Accordingly, its popularity as a refrigerant is on the increase once again.

[0004] The properties and characteristics of carbon dioxide are quite different from those of conventional vapour compression cycle refrigerants. With a critical temperature of around 31°C most vapour compression cycles operating with carbon dioxide will do so close to the critical point of carbon dioxide. In simple cycle operation, the theoretical efficiency of carbon dioxide is generally lower than that of other commercially available refrigerants. However, recent developments have shown that the efficiency, in practice, of a two phase mechanical refrigeration cycle using carbon dioxide and operating above the critical point can be competitive with current refrigeration systems. This cycle is commonly referred to as the trans-critical cycle.

[0005] In the current form of the carbon dioxide trans-critical cycle, gaseous carbon dioxide is first compressed to a pressure and temperature above its critical point. The high pressure gas is then cooled and passed through a throttling device which allows the refrigerant to form a gas/liquid mixture at constant enthalpy. The mixture is then finally evaporated back to a gas. Increased efficiency is achieved because the internal losses of the cycle are typically lower than that of a conventional vapour compression cycle.

[0006] Despite this improvement, it remains desirable to increase the efficiency of the carbon dioxide trans-critical cycle further. While the present invention was developed specifically with the trans-critical cycle in mind, it is believed to have wider application, to vapour compression cycles in general, operating with a range of refrigerant materials.

Summary of the Invention

[0007] According to one aspect of the present invention, a two-phase mechanical refrigeration system comprises

(i) a primary compressor for compressing a gaseous refrigerant to a first elevated pressure and a first elevated temperature;
(ii) connected to the primary compressor, a cooler for cooling the gaseous refrigerant from step (i) at substantially constant pressure, to form a cooled gas or a gas/liquid mixture at a second temperature;
(iii) connected to the cooler, an expander for expanding substantially all the gas or gas/liquid mixture from step (ii) to form a gas/liquid mixture at a second pressure lower than the first pressure, and a third temperature, lower than the second temperature;
(iv) an expansion valve for expanding the gas/liquid mixture, or the liquid portion thereof, at substantially constant temperature, to a third pressure lower than the second pressure;
(v) connected to the expansion valve, an evaporator for evaporating the gas/liquid mixture, or the liquid portion thereof, at substantially constant pressure to form a gas;
(vi) connected between the evaporator and the primary compressor, a secondary compressor for compressing the gas exiting the evaporator in step (v) to a fourth pressure intermediate the first pressure and the third pressure, and preferably substantially equal to the second pressure, wherein the secondary compressor is driven by the energy produced by the expander in expanding the gaseous refrigerant in step (iii) to form the gas/liquid mixture; and

(vii) a liquid accumulator, positioned either between the expander and the evaporator or between the evaporator and the secondary compressor, for collecting liquid refrigerant.

[0008] The principal difference between the present invention and a conventional two-phase mechanical refrigerant system is the inclusion of a secondary, or intermediate, compressor to pre-compress gas returning to the primary compressor. This has the effect of reducing the pressure differential across the primary compressor, rendering that compressor more efficient and reducing the work it needs to do to compress the gaseous refrigerant.

[0009] The secondary compressor is itself driven by the work generated in the expander by expansion of the refrigerant material. In the past, consideration has been given as to whether use may be made of the work generated on expansion. However, prior to the present invention it was generally accepted that the amount of effective work done was so small as to be of no practical benefit. One application where the work done on expansion has been used to positive effect is in the so-called "Boot Strap" air conditioning system utilised in aircraft. However, this system is a one phase gas compression system, which utilises the work done on expansion to drive an intermediate compressor rather than to pre-compress the gas for the primary compressor.

[0010] In addition to increasing the efficiency of the primary compressor, in the present invention the total cycle efficiency is increased, as judged by the coefficient of performance (COP), compared to conventional two-phase mechanical refrigeration cycles.

[0011] According to a further aspect of the present invention, the two-phase mechanical refrigeration system described above is incorporated into a refrigeration or air conditioning apparatus or system, or a heat pump. A preferred application of the present invention is in vehicle air conditioning, for instance in automobiles, aircraft and ships, most preferably in automobiles. The refrigeration system of the present invention may also find use in buildings or on fixed sites, such as industrial plants, for any of the above applications. These represent further aspects of the present invention.

[0012] According to yet a further aspect of the present invention, a process for providing refrigeration or air conditioning comprises the following steps:

(i) compressing a gaseous refrigerant to a first elevated pressure and a first elevated temperature;
(ii) cooling the gaseous refrigerant from step (i) at substantially constant pressure, to form a cooled gas or a gas/liquid mixture at a second temperature;
(iii) expanding substantially all the gas or gas/liquid mixture from step (ii) to form a gas/liquid mixture at a second pressure, lower than the first pressure, and a third temperature lower than the second temperature;
(iv) expanding, or throttling, the gas/liquid mixture, or the liquid portion thereof, at substantially constant temperature to reduce its pressure to a third pressure lower than the second pressure;
(v) evaporating the gas/liquid mixture, or liquid portion thereof, from step (iv), at substantially constant pressure to form a gas;
(vi) utilising energy produced on expansion in step (iii), compressing the gas exiting the evaporator in step (iv) to a fourth pressure, intermediate the first pressure and the third pressure, and preferably substantially equal to the second pressure; and
(vii) recycling the gas from step (vi) to step (i), wherein the change of state taking place in step (ii) and/or step (v) is used to provide a heating and/or cooling effect, respectively.

Detailed Description of the Invention

[0013] In the context of the present invention, where the term "refrigeration" alone is used it is intended to embrace commercial and domestic refrigeration, air conditioning and heat pump applications. Furthermore, the term "gas" is intended to include lightly saturated vapour.

[0014] The two-phase mechanical refrigeration system of the present invention can be used, with appropriate modification, for a variety of refrigerant materials, above or below the critical point of the respective refrigerant material. Suitable examples include carbon dioxide, ammonia, and chlorofluorocarbon and hydrofluorocarbon refrigerants. Preferably the system is operated using carbon dioxide as the refrigerant, more preferably under conditions of a trans-critical vapour compression cycle, as it is in this cycle that the most significant improvement in efficiency is observed.

[0015] Accordingly, the present invention is now described in more detail in terms of a carbon dioxide trans-critical cycle, but the components described and their mode of operation are generally applicable to other refrigerants and to other vapour compression cycles. Reference is made to the following drawings:

Figure 1 is a schematic diagram of a conventional two-phase mechanical refrigeration system running on a carbon dioxide trans-critical cycle.
Figure 2 is a schematic diagram of a two-phase mechanical refrigeration system according to the present invention

running on a carbon dioxide trans-critical cycle.

Figure 3 is a modification of the schematic diagram shown in Figure 2, incorporating a heat exchanger.

Figure 4 shows an additional or alternative position for the heat exchanger shown in Figure 3.

Figure 5 is the pressure/enthalpy diagram for the system of Figure 1, when operated as an air conditioning system using carbon dioxide above its critical point.

Figure 6 is the pressure/enthalpy diagram for the system of Figure 2, when operated as an air conditioning system using carbon dioxide above its critical point.

[0016] With reference to Figure 1, gaseous carbon dioxide enters a compressor (11) where it is compressed to a pressure and temperature above its critical point. The gas is then cooled by cooler (12), throttled by way of expansion valve (13) to reduce its pressure, and then subject to evaporation in evaporator (14). The gas/liquid mixture exiting the evaporator enters liquid accumulator (15), and the gas separated is recycled to the primary compressor via heat exchanger (18), which serves to cool gas en route from cooler (12) to expansion valve (13).

[0017] With reference to Figure 2, on entering the primary, or main, compressor (21), gaseous carbon dioxide is compressed to a pressure and temperature above its critical point. The high pressure gas then enters the gas cooler (22), where its temperature is reduced while maintaining its pressure substantially constant. This can result in the formation of a gas/liquid mixture, depending on the conditions and the refrigerant employed. However, in the case of carbon dioxide generally a cooled high pressure gas will be formed. Up to this point, the basic functions of the two phase mechanical refrigeration system of the invention are essentially the same as the standard trans-critical system described in relation to Figure 1.

[0018] Substantially all the high pressure gas, or the gas/liquid mixture if appropriate, emerging from the gas cooler then enters an expander (23), where the gas is expanded to a lower, intermediate, pressure and temperature resulting in formation of a gas/liquid mixture at I_e'. By substantially all the gas, or gas/liquid mixture, we mean all the gas or gas/liquid mixture other than small amounts, for instance up to 5 wt.%, of refrigerant material that may be lost, for instance, through internal leakage. In particular, the system of the invention does not include a device for separating off some of the refrigerant material prior to expansion through the expander. This mixture then enters a combined gas separator/liquid accumulator (24), which separates the gaseous portion of the mixture for recycling to point X, prior to the primary compressor, and directs the liquid portion of the mixture through an expansion, or throttle, valve (25), and to an evaporator (26).

[0019] In another embodiment of the present invention, a liquid accumulator can be positioned after the evaporator, as in the conventional trans-critical cycle shown in Figure 1. In this case, a simple expansion or throttling valve with no feedback mechanism can be used, although the positioning of liquid accumulator after the evaporator is critical, to prevent liquid entering, and therefore damaging, the compressors used in the cycle. Preferably means are provided to separate the gaseous refrigerant from the gas/liquid mixture prior to its entry into the expansion valve. The gas separated in this manner is then recycled to the primary compressor.

[0020] Generally, however, it is preferred to position a combined gas separator/liquid accumulator after the gas cooler but before the expansion valve, to ensure that there is always sufficient refrigerant in the system and that only liquid enters the expansion or throttling valve.

[0021] Evaporation and cooling take place in the evaporator (26) as in a conventional refrigeration system, resulting in a gas at relatively low temperature and pressure. The gas leaving the evaporator then enters a secondary, or intermediate, compressor (27) which is connected to the expander (23) and the power generated by the expander drives this compressor. Generally, there is no need for a secondary power source, for instance a motor, to drive the secondary compressor. Typically, the secondary compressor is directly connected by mechanical means, for instance by a shaft, to the expander. The secondary compressor acts to compress gas to a pressure intermediate that of the pressure of the gas exiting the evaporator and the pressure achieved by way of the primary compressor.

[0022] In an ideal system, this intermediate pressure would be equal to the pressure of the gas/liquid mixture obtained after expansion in the expander (23). In a real system, however, it is inevitable that some pressure losses will occur. Accordingly, in the context of the present invention, when we refer to this intermediate pressure being substantially equal to the pressure obtained after expansion, we take into account pressure losses typically incurred in operating a mechanical refrigeration cycle. In practice the amount of pressure loss can vary quite considerably, from as low as a few percent on the high pressure side of the cycle to up to 20%, or higher, on the low pressure side of the cycle.

[0023] The expander/secondary compressor unit is self-regulating, in that a balance of pressure will be achieved once the expander power output is equal to the work done in driving the secondary compressor and overcoming the friction associated therewith. This is, therefore, a stable system, with negative feedback, rendering any external controls or regulation unnecessary.

[0024] The gas exiting the secondary compressor under conditions I_c' then mixes with the gas from the liquid gas separator/liquid accumulator, at point X. The gas mixture then enters the primary compressor, and the vapour compression cycle is completed.

[0025] While at point X the separate gas streams will eventually achieve the same pressure, they may be at different conditions of temperature and enthalpy. In this case, some potential cooling effect will be lost at point X in the cycle. This loss can be recovered in two ways. The gas from the gas separator/liquid accumulator may be used to cool the gas from the gas cooler, by way of gas-to-gas heat exchanger. Alternatively, or additionally, the gas from the gas separator/liquid accumulator may itself be used to cool a body, or to pre-cool outside air entering a vehicle, for instance by way of an air-to-gas heat exchanger.

[0026] Reference is made to Figure 3, in which the reference numerals used in Figure 2 are used to denote the corresponding components of the mechanical refrigeration system. Gas-to-gas heat exchanger (28) achieves additional cooling of the gas exiting the gas cooler, by way of the gas separated from the gas separator/accumulator, thereby increasing the overall performance and efficiency of the system.

[0027] Figure 4 shows an additional, or alternative, position for a heat exchanger to be incorporated into the system shown in Figure 3, across points Y and Z. Liquid-to-gas heat exchanger (29) is positioned after the gas separator/accumulator and prior to the expansion valve. It functions by allowing the cold gas exiting the evaporator (26) to pre-cool the liquid flowing from the gas separator to the expansion or throttling valve (25). Again, this has the effect of increasing the overall performance and efficiency of the system.

[0028] The types of components for use in the system of the present invention, i.e. the compressors, gas cooler (or condenser), expanders and evaporators may be any of the components conventionally used in vapour compression system. The gas cooler is referred to as such because it acts simple to cool the gas, rather than condense a portion of that gas into liquid. Any conventional condenser can be used for this purpose.

[0029] In a preferred embodiment of the present invention, the expander and/or compressors comprise axial or radial turbines, for instance of the type used in engine turbochargers. Radial turbine expanders and compressors are particularly preferred. A further consequence of the use of the expander/secondary compressor unit is that the gas returned to the primary compressor, on completion of the refrigeration cycle, is higher and denser than for the standard trans-critical cycle. Thus, the primary compressor can be reduced in size inversely proportional to the increase in gas density observed, allowing a cost saving. Furthermore, the expander and/or compressors may be made of lightweight materials, such as aluminum and plastics reinforced with, for instance, glass or other mineral fibres. The combined benefit of reduced dimensions and reduced material and manufacturing costs makes the use of such turbines particularly attractive in the field of automobile air conditioning.

[0030] For optimum performance, a seal should be provided between the expander the secondary compressor, to reduce leakage of refrigerants. Any suitable seal may be utilised for this purpose, for instance a lip type dynamic seal.

[0031] The system may include a control device, or feedback mechanism, for the expansion or throttling valve. The advantage of using a control device is two-fold. First, all the liquid is converted to gas in the evaporator, thereby maximising the available cooling effect. Second, no liquid can return to the compressor, and so the conventional hazards of pumping liquid are avoided.

[0032] An example of an expansion valve which includes a control device of this type is controlled in this manner is a so-called thermostatic expansion valve (TXV). The valve is responsive to a sensor positioned after the evaporator which measures the thermodynamic characteristics of the material leaving the evaporator. As has been mentioned above, one of the preferred applications of the present invention is in vehicle air conditioning, and in particular automobile air conditioning.

[0033] The system according to the invention may be incorporated as an air conditioning system in the conventional way. For instance, typically the system of the invention will be used to provide a cooling effect and will be arranged in parallel with a heating system, behind the dashboard of an automobile. Means are provided, typically in the form of air flaps, to vary the amount of air, which enters the automobile from the outside, passing through the system of the present invention and through the heating system arranged in parallel therewith, in order to achieve the desired environment within the automobile.

System Efficiency

[0034] Figure 5 shows the pressure/enthalpy diagram for a carbon dioxide trans-critical cycle, marked up to correspond to points on the schematic shown in Figure 1. The conditions of pressure, temperature and enthalpy at each of the points in the cycle are listed in Table 1 below, as for an air conditioning system. For simplicity, the contribution made by the heat exchanger (18) is not included.

Table 1

Point	Pressure (kPa)	Temperature (°C)	Enthalpy (kJ/kg)
1	3500	4	323.9

Table 1 (continued)

Point	Pressure (kPa)	Temperature (°C)	Enthalpy (kJ/kg)
2	11500	97.2	374.7
2'	11500	110.5	391.6
3	11500	50	230.5
4	3500	0.2	230.5

[0035] Figure 6 shows the pressure/enthalpy diagram for a carbon dioxide trans-critical cycle, marked up to correspond to points on the schematic in Figure 2. The conditions of pressure, temperature and enthalpy at each of the points in the cycle are listed in Table 2 below, as for an air conditioning system.

[0036] I_{vapour} represents the gas exiting the gas separator (24), I_c' the gas exiting the intermediate compressor, and I_{liquid} the liquid exiting the gas separator/liquid accumulator.

Table 2

Point	Pressure (kPa)	Temperature (°C)	Enthalphy (kJ/kg)
X	3500	4	323.9
I_{vapour}	5500	18.3	298.6
X	5500	26.7	321.8
I_c	5500	37	341.6
I_c'	5500	39.6	346.0
2	11500	34.5	351.1
2'	11500	89.5	360.9
3	11500	50	230.5
I_{liquid}	5500	18.3	136.2
I_e	5500	18.3	217.1
I_e'	5500	18.3	219.1
4	3500	0.2	136.2

[0037] In each pressure/enthalpy diagram, the dashed lines represent isentropic compression or expansion.

[0038] The isentropic efficiency of the primary compressor in the systems of Figures 1 and 2 is assumed to be 0.75, which is typical for piston compressor. The isentropic efficiency of the secondary compressor in the cycle shown in Figure 2 is assumed to be 0.80, which is typical for a radial turbine compressor.

[0039] Based upon the use of one kilogram of carbon dioxide refrigerant in each system, and the separation of 0.51 kg of gas to be recycled to the primary compressor and 0.49 kg of liquid to pass to the expansion valve in Figure 2, the coefficient of performance (COP) for the system of Figure 2 can be calculated to be 2.35. In contrast, the COP calculated for the conventional system shown in Figure 1 can be calculated to be 1.38. The system of the present invention is, therefore, considerably more efficient than the conventional system.

[0040] Furthermore, it can be shown that the power produced by the expander is equal to the power absorbed by the compressor and can overcome the normal mechanical losses in operating such equipment.

[0041] As would be understood by the skilled man, performance of the system can be further improved through use of one or a number of appropriately positioned heat exchangers.

Claims

1. A two-phase mechanical refrigeration system comprising

    (i) a primary compressor for compressing a gaseous refrigerant to first elevated pressure and a first elevated temperature;

(ii) connected to the primary compressor, a cooler for cooling the gaseous refrigerant from step (i) at substantially constant pressure to form a cooled gas or a gas/liquid mixture at a second temperature;
(iii) connected to the cooler, an expander for expanding substantially all the gas or gas/liquid mixture from step (ii) to form a gas/liquid mixture at a second pressure lower than the first pressure, and a third temperature lower than the second temperature;
(iv) an expansion valve for expanding the gas/liquid mixture, or the liquid portion thereof, at substantially constant temperature, to a third pressure lower than the second pressure;
(v) connected to the expansion valve, an evaporator for evaporating the gas/liquid mixture, or the liquid portion thereof, at substantially constant pressure to form a gas;
(vi) connected between the evaporator and the primary compressor, a secondary compressor for compressing the gas exiting the evaporator in step (v) to a fourth pressure intermediate the first pressure and the third pressure, wherein the secondary compressor is driven by the energy produced by the expander in expanding the gaseous refrigerant in step (iii) to form the gas/liquid mixture; and
(vii)a liquid accumulator, positioned either between the expander and the evaporator or between the evaporator and the secondary compressor, for collecting liquid refrigerant.

2. A system according to claim 1, wherein in step (vi) the fourth pressure is substantially equal to the second pressure in step (iii).

3. A system according to claim 1 or claim 2, which further comprises a gas separator positioned between the expander and the expansion valve, for separating gas from the gas/liquid mixture produced by the expander, and which preferably further comprises means for recycling the gas separated by the separator to the primary compressor.

4. A system according to claim 3, which comprises a combined gas separator and liquid accumulator positioned between the expander and the expansion valve.

5. A system according to claim 3, where the liquid accumulator is positioned between the evaporator and the primary compressor.

6. A system according to claim 4 or claim 5, which comprises means for recycling the gas separated by the separator to the primary compressor, and which further comprises a gas-to-gas heat exchanger positioned between the combined gas separator and liquid accumulator and the primary compressor, for cooling gas supplied to the expander by the gas cooler.

7. A system according to any of claims 4 to 6, which comprises means for recycling the gas separated by the separator to the primary compressor, and which further comprises a liquid-to-gas heat exchanger positioned between the combined gas separator and liquid accumulator and the expansion valve.

8. A system according to any preceding claim, wherein at least one of the primary and secondary compressor and/or the expander comprises a turbine, preferably a radial turbine, more preferably a radial turbine made from aluminum or reinforced plastics material.

9. A system according to any preceding claim which contains carbon dioxide as the refrigerant and which operates in accordance with a trans-critical vapour compression cycle.

10. Apparatus selected from refrigeration apparatus, air conditioning apparatus and heat pumps comprising a system as defined in any preceding claim.

11. A vehicle, preferably an automobile, comprising, as an air conditioning system, a system as defined in any of claims 1 to 9.

12. Use as an air conditioning system in a building or another fixed site, of a system as defined in any of claims 1 to 9.

13. A process for providing a cooling and/or heating effect comprising the following steps:

(i) compressing a gaseous refrigerant to a first elevated pressure and a first elevated temperature;
(ii) cooling the gaseous refrigerant from step (i) at substantially constant pressure to form a cooled gas or a

gas/liquid mixture at a second temperature;
(iii) expanding substantially all the gas or gas/liquid mixture from step (ii) to form a gas/liquid mixture at a second pressure, lower than the first pressure and a third temperature lower than the second temperature;
(iv) expanding the gas/liquid mixture, or the liquid portion thereof, at substantially constant temperature to reduce its pressure to a third pressure lower than the second pressure;
(v) evaporating the gas/liquid mixture, or the liquid portion thereof, from step (iv) at substantially constant pressure to form a gas;
(vi) utilising energy produced on expansion in step (iii), compressing the gas exiting the evaporator in step (v) to a fourth pressure intermediate the first pressure and the third pressure; and
(vii)recycling the gas from step (vi) to step (i), wherein the change of state taking place in step (ii) or step (v) provides the heating and/or cooling effect, respectively.

14. A process according to claim 13, wherein in step (vi) the fourth pressure is substantially equal to the second pressure in step (iii)

15. A process according to claim 13 or claim 14, which further comprises separating gas from the gas/liquid mixture formed in step (iii), and recycling the gas to step (i).

16. A process according to any of claims 13 to 15, wherein the refrigerant is carbon dioxide, and the process operates in accordance with a trans-critical vapour compression cycle.

Fig.1.

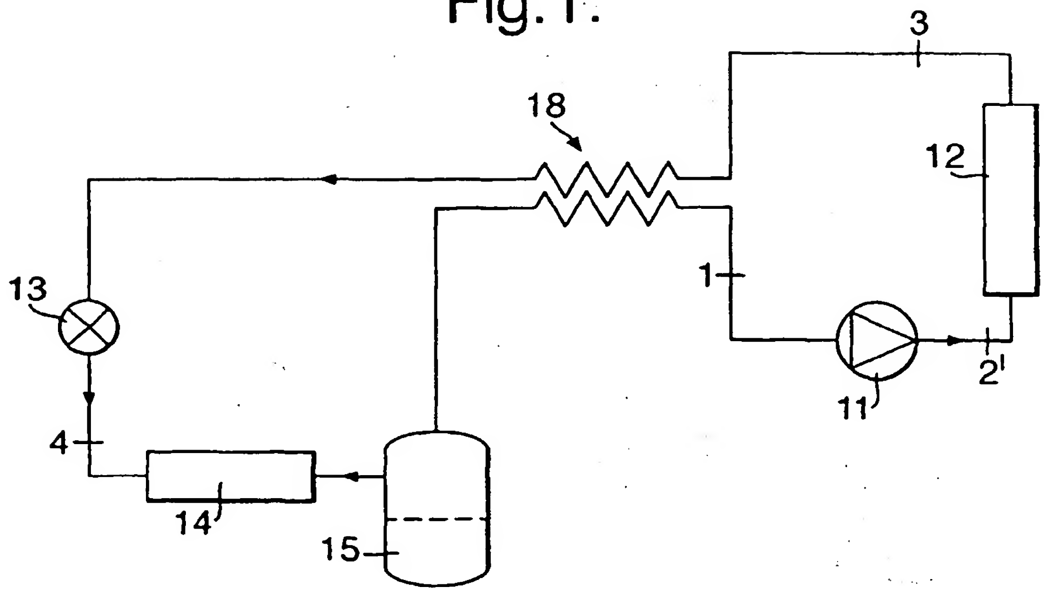


Fig.2.

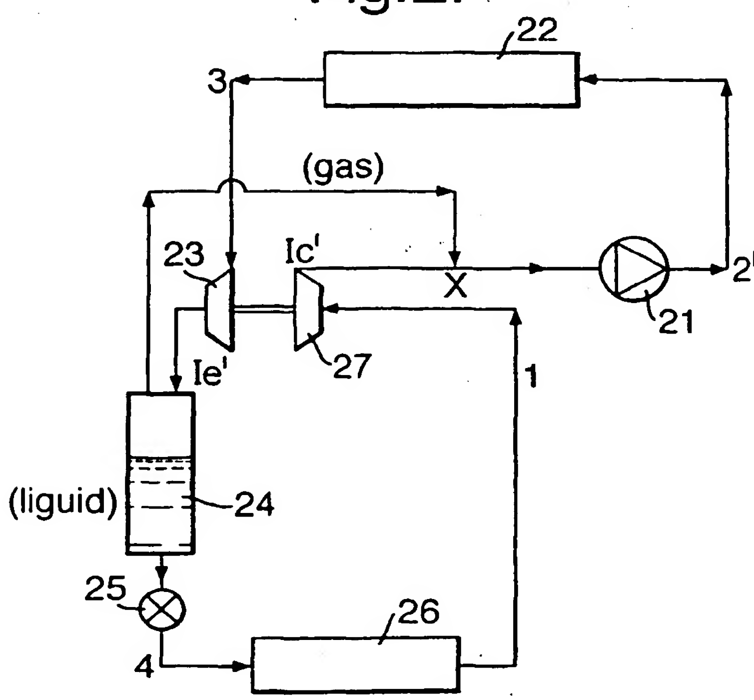


Fig.3.

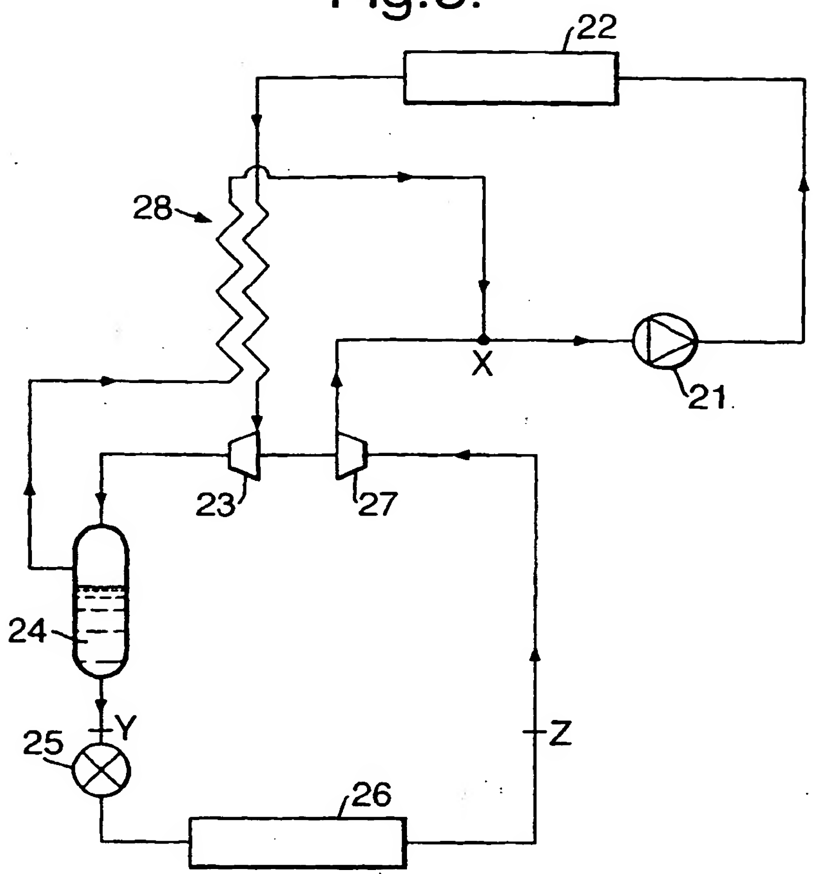


Fig.4.

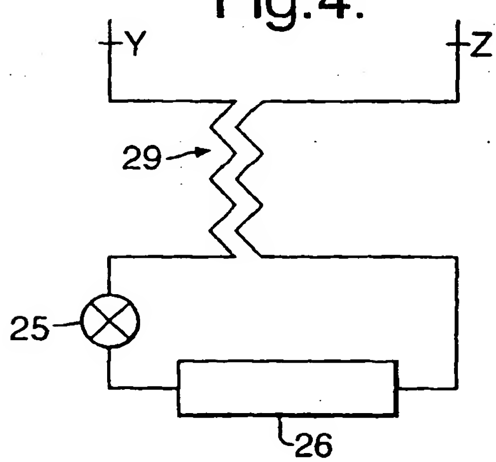


Fig.5.

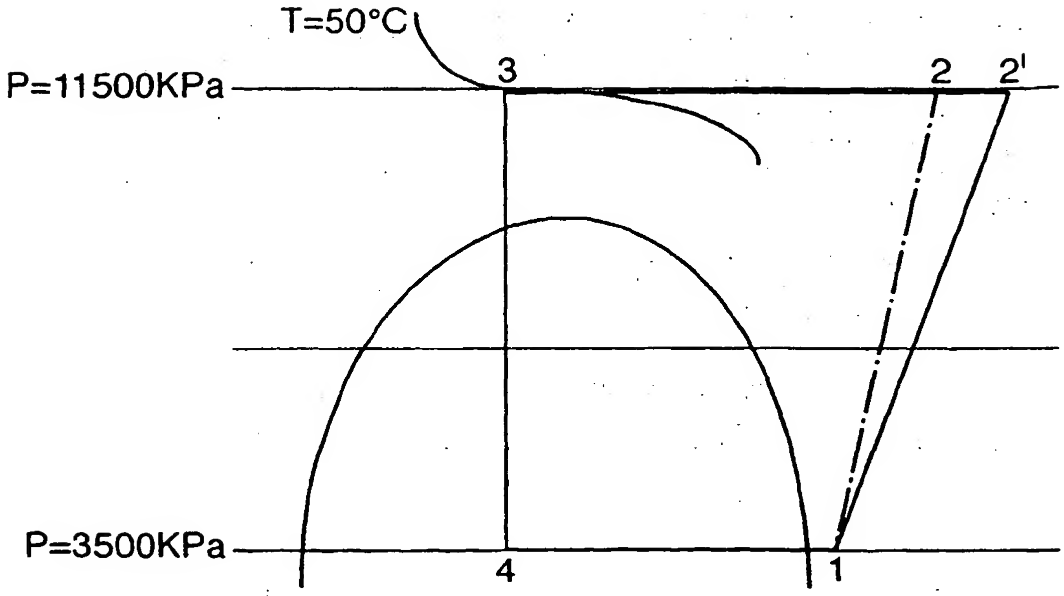
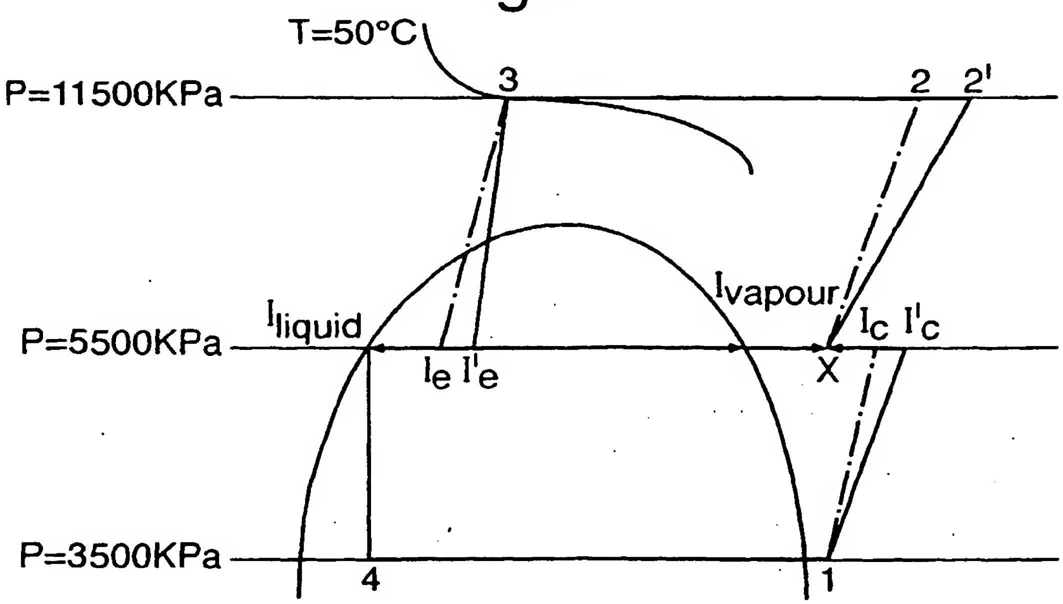

T=50°C
P=11500KPa
3
2
2'
P=3500KPa
4
1

Fig.6.


T=50°C
P=11500KPa
3
2
2'
Iliquid
Ivapour
P=5500KPa
Ie I'e
Ic I'c
X
P=3500KPa
4
1

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 30 3315

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
Y A	US 2 494 120 A (B.J.FERRO) 10 January 1950 (1950-01-10) * column 1, line 44 - column 4, line 31; figure 1 *	1,3,4,8, 10,13 6,7	F25B1/10 F25B9/00 F25B11/02
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TECHNICAL FIELDS SEARCHED (Int.Cl.7)

F25B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21 June 2000	Jessen, F

CATEGORY OF CITED DOCUMENTS

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21-06-2000

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